Lawrence Livermore National Laboratory

ORNL OAK RIDGE NATIONAL LABORATORY

BERKELEY LAB

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(http://www-esd.lbl.gov/GEOSEQ)

GEO-SEQ Project

Monitoring Technology • Cost Optimization • Capacity Assessment • Performance Assessment Models • Public Outreach

A National Energy Technology Laboratory (NETL) Supported Project

NETL NATIONAL ENERGY TECHNOLOGY LABORATORY

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Overview

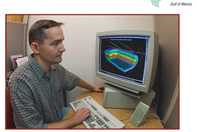
GEO-SEQ

- A public-private R&D partnership to deliver technologies and information needed for safe, cost-effective geologic sequestration of CO_2 by 2015
- Three National Labs:
  - Lawrence Berkeley National Laboratory
  - Lawrence Livermore National Laboratory
  - Oak Ridge National Laboratory
- Other research partners include USGS, Stanford University, Texas Bureau of Economic Geology, Alberta Research Council
- Industry Partners
  - Chevron
  - Texaco
  - Pan Canadian Resources
  - BP-Amoco
  - Statoil
- Leverages scientific knowledge from the Office of Science and DOE/Fossil Energy

Pilot Test Sites

Our industry partners are providing three pilot test sites for evaluating technologies for monitoring sequestration of CO_2 in geologic formations. These include the Lost Hills Oil Field (Chevron) in the Central Valley, California, the Vacuum Oil Field (Texaco) near Hobbs, New Mexico, and the Weyburn Field (Pan Canadian Resources) near Regina, Saskatchewan. These pilot test sites will be used to evaluate how effectively high-resolution geophysical techniques, such as single- and cross-well seismic imaging, cross-well electromagnetic imaging, and possibly electrical resistance tomography, can track the migration of CO_2 in geologic formations. We shall also use the pilot tests as an opportunity to develop tracer techniques for evaluating *in situ* CO_2 solubilization and mineralization rates.

If additional sites become available, they will be evaluated as possible candidates for pilot testing of monitoring techniques or for evaluating newly developed co-optimization technologies from Task A.



Benefits

Lower Sequestration Costs
- Co-optimize sequestration and fossil fuel production
- Understand and optimize trade-offs between injection, transportation and separation costs for deep brine formations

Lower Sequestration Risk
- Provide information needed to evaluate the capacity and siting for sequestration in deep brine formations
- Increase confidence and safety by demonstrating innovative monitoring and tracking technologies
- Enhance performance assessment models

Decrease Time to Implementation
- Pursue early opportunities to do pilot tests and gain acceptance by the private sector
- Develop the enabling technology for safe and effective sequestration

Public Acceptance
- Provide information to the public and regulatory agencies
- Gain input on criteria for successful geologic sequestration

GEO-SEQ Project
Director: Sally M. Benson
Project Manager: Larry Myer

- Advisory Council
- Outreach
- **Task A** Cost-Optimization: F. Orr, Stanford; C. Oldenburg*, LBNL; K. Knauss, LLNL; K. Yuracko, ORNL
- **Task B** Monitoring: L. Myer*, LBNL; M. Hoversten, LBNL; R. Newmark, LLNL; E. Majer, LBNL; D. Cole, ORNL; G. Moline, ORNL
- **Task C** Performance Assessment: W. Gunter, ARC; K. Pruess*, LBNL; C.-F. Tsang, LBNL
- **Task D** Capacity Assessment: S. Benson*, LBNL; R. Burruss, USGS; S. Hovorka, TBEG

*Coordinator

Task A: Develop Sequestration Co-optimization Methods for Enhanced Oil Recovery (EOR), Depleted Gas Reservoirs and Brine Formations

A-1: Co-optimization of Carbon Sequestration and EOR and Enhanced Gas Recovery (EGR) from Oil Reservoirs

Issues
- Availability of lower cost CO_2 will expand the number of oil reservoirs that will be used for CO_2 EOR. Expanded screening criteria are needed to select these.
- Methods are needed to simultaneously optimize CO_2 sequestration and EOR

Benefits
- Lower the cost of sequestration
- Greater sequestration efficiency in EOR projects
- Provide the framework for rapid evaluation and selection of candidate sites for combined EOR and sequestration

R&D Team
Franklin Orr and Anthony Kovscek, Stanford University

A-2: Assess Feasibility to Sequester CO_2 in Depleted Natural Gas Formations while Enhancing Natural Gas Recovery

Issues
- Enhanced natural gas recovery during CO_2 sequestration has not been evaluated
- Industry is concerned that CO_2 injection will degrade the quality of produced gases

Benefits
- Add a new option for geologic sequestration with value-added benefits
- Sustain production rates in mature natural gas fields
- Minimize subsidence in natural gas fields
- Lower the cost of sequestration

R&D Team
Curt Oldenburg and Sally Benson, LBNL
Tony Kovscek, Stanford University

A-3: Evaluate Impact of CO_2, Water and Reservoir Rock Interactions on Geologic Sequestration of CO_2

Issues
- Costs for sequestration may be reduced if lower purity CO_2 streams are sequestered
- Environmental and cost impacts of injecting lower quality waste streams are not understood

Benefits
- Lower the overall cost of geologic sequestration
- Gain regulatory approval for sequestering impure CO_2 waste streams

R&D Team
Kevin Knauss and Carl Steefel, LLNL
Karsten Pruess and Chin-Fu Tsang, LBNL

A-4: Life Cycle Cost Analysis

Issues
- Reliable estimates of the cost of sequestration in brine formations are not available

Benefits
- Identify ways to lower costs through trade-offs between separation, compression, transportation and formation-specific costs
- Estimate risks and cost uncertainties between options
- Gain industry and regulatory acceptance

R&D Team
Katherine Yuracko, ORNL

Task B: Monitoring Technologies for Verification, Optimization and Safety

B-1: Sensitivity Modeling and Optimization of Geophysical Monitoring Technologies

Issues
- Sensitivity of candidate geophysical methods is not known
- Monitoring strategies have not been developed

Benefits
- Full evaluation and demonstration of candidate geophysical monitoring techniques
- Design specifications for monitoring optimization
- Synthesis of existing & new high resolution geophysical imaging algorithms

R&D Team
Larry Myer, Mike Hoversten, Don Vasco and Ernie Majer, LBNL
Robin Newmark, LLNL

B-2: Field Data Acquisition for CO_2 Monitoring; Geophysical Methods

Issues
- Field demonstration of integrated high resolution geophysical techniques have not been carried out

Benefits
- Provide test results and demonstrate applicability of high resolution seismic, EM, ERT monitoring technologies at various industry test sites at different sites and in different formations:
  - Lost Hills, CA (Chevron)
  - Vacuum Field, NM (Texaco)
  - Weyburn Field, Saskatchewan (Pan Canadian Res.)
  - Fenn-Big Valley, Alberta (ARC)

R&D Team
Ernie Majer and Mike Hoversten, LBNL
Robin Newmark, LLNL

B-3: Application of Natural and Introduced Tracers for Optimizing Value-Added Sequestration Technologies

Issues
- Multiple hydrodynamic and chemical processes affect fate and transport of CO_2, residence time, and reservoir storage capacity
- Do tracers of stable isotopes (O, S, C, N), noble gases isotopes, radioactive isotopes provide the means to monitor the effectiveness of CO_2 injection and sequestration?

Benefits
- Field and laboratory test data will permit assessment of the effectiveness of tracers used to monitor CO_2 sequestration processes
- A complete chemical assessment of the predictive capabilities of natural and introduced tracers

R&D Team
David Cole and Jerry Moline, ORNL

Task C: Improve Performance Assessment Models

C-1: Enhance Numerical Simulators for Greenhouse Gas Sequestration in Deep Unminable Coal Seams

Issues
- Based on recent field tests (ARC) in Alberta there are reasons to believe that coalbed simulators do not have features to correctly model process physics for CO_2 sequestration

Benefits
- Enhancement of one or more of the existing simulators with the addition of algorithms that account for a fuller suite of gas-rock physical/chemical effects
- Validation of enhanced simulators by doing history matches to field data

R&D Team
Bill Gunter and David Law, ARC
Karsten Pruess, LBNL
Bert van der Meer, TNO
Franklin Orr and Anthony Kovscek, Stanford University

C-2: Intercomparison of Reservoir Simulation Models for Oil, Gas, and Brine Formations

Issues
- Many research and industrial groups have simulation capability relevant to CO_2 sequestration
- Simulation codes need enhanced capabilities to reliably predict the long-term fate of sequestered CO_2
- Simulation intercomparisons and improvements can be achieved by mobilizing a community of researchers to solve a set of benchmark problems

Benefits
- Cost effective approach to enhance simulation capability for CO_2 sequestration
- Improved simulation capability
- Gain public confidence and regulatory acceptance for CO_2 sequestration

R&D Team
Karsten Pruess and Chin-Fu Tsang, LBNL
Kevin Knauss and Carl Steefel, LLNL

Task D: Improve Methodology and Information Available for Sequestration Capacity Assessment

Issues
- Accurate information on the location and capacity of geologic sequestration sites is needed
- Reliable estimates of the storage efficiency are needed
- Accurate information of the location and size of CO_2 sources is needed

Benefits
- Linked GIS databases synthesizing work currently underway by TBEG and U.S. Geological Survey will be put into a common platform and made web-accessible
- More reliable estimates of sequestration capacity and promising sites

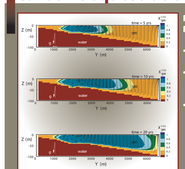
R&D Team
Sally Benson and Karsten Pruess, LBNL
Susan Hovorka, University of Texas
Bob Burruss, USGS

Public Outreach

- Middle School Education
- Undergraduate and Graduate School Research Opportunities
- Stakeholder Information

Accomplishments

Carbon Sequestration Enhanced Gas Recovery



Simulated CO_2 migration at 5, 10 and 20 years after injection into the Rio Vista Gas Field at the rate equivalent to the CO_2 generated from a 680 MW gas-fired power plant.

Process Modeling of Carbon Sequestration Enhanced Gas Recovery

- Process modeling capabilities are being developed using the TOUGH2 simulator
- A case study for the Rio Vista Gas Field, California shows natural gas production can be enhanced before CO_2 breakthrough occurs
- Many important issues remain to be addressed, including:
  - Influence of reservoir heterogeneity
  - Role of water drive
  - Optimal injection and extraction strategies

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Capacity Assessment

Brine-bearing formations have great potential for long-term storage and disposal of greenhouse gases. Extensive industry experience demonstrates that disposal into geologic environments is feasible using existing technology, and that residence time for injected CO_2 would be adequate to prevent significant negative impact on overlying potable water or the atmosphere.

We identified 14 significant geological attributes that impact the feasibility of injection and containment of CO_2 that can be determined for saline formations using a variety of approaches:

- depth
- permeability
- sand-body thickness
- net sand thickness
- percent shale
- sand-body continuity
- top seal thickness
- continuity of top seal
- hydrocarbon production from interval
- fluid residence time
- flow direction
- CO_2 solubility in brine
- rock/water reaction
- porosity

A database from 21 basins has been developed that includes information about these 14 important variables. The GEO-SEQ Project Team will use these data to conduct realistic numerical simulations to assess the sequestration capacity of representative formations.

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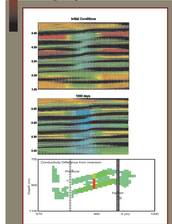
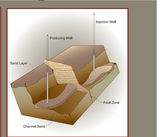
Geophysical Monitoring





Results of seismic and electromagnetic processing showing changes due to CO_2 movement.

Assessment of surface seismic and crosswell electromagnetic techniques for monitoring migration of CO_2:

- Reservoir simulations showed migration of CO_2 up a fault from the lower channel sand to the upper channel sand
- Numerical modeling showed that seismic and electromagnetic imaging would detect the CO_2 in the fault
- Field testing of seismic and electromagnetic techniques are currently underway

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Publications

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